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A Hawaiian beginning for the Iceland plume: Modelling of reconnaissance data for olivine-hosted melt inclusions in Palaeogene picrite lavas from East Greenland

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Abstract

Compositions of parental and primary melts are modelled for olivine-hosted melt inclusions in three, Palaeogene, proto-Iceland plume picrite samples from East Greenland. The samples represent three stages in the magmatic evolution: (1) the early pre-spreading volcanics of the Lower Basalts, (2) the early plateau basalts in the Milne Land Formation and (3) the steady stage plateau basalt of the Geikie Plateau Formation. The observations suggest that the host lavas are variably mixed with melts and material from the wall rocks of the feeder system. Pressure estimates based on K_D between olivine and reconstructed melt composition suggests the melts to be trapped in their hosts during ascent from magma chambers near the base of the East Greenland crust. CaO/Al_2O_3 ratios suggest initiation of melting in the proto-Iceland plume at pressures up to 5–6 GPa and segregation depths mainly between 3 and 4 GPa. Early melts show marked similarities in major and trace elements with primary Hawaiian type melts. It is proposed that the continental separation in the North Atlantic was influenced by a pre-seafloor spreading rise of a “Hawaiian” type plume with a significant component of recycled basalt.

Keywords: Picrites; Palaeogene; East Greenland; Melt inclusions; Primary melts; Hawaiian type

1. Introduction

The up to ca. 8 km thick Palaeogene East Greenland plateau basalts formed prior to and during the continental break-up in the North Atlantic. Most of the plateau basalts are tholeiitic and quite evolved basaltic lavas (e.g., Brooks and Nielsen, 1982; Larsen et al., 1989; Fram and Lesher, 1997; Tegner et al., 1998a; Andreasen et al., 2004). The tholeiitic lavas are the result of magma pooling and fractionation in crustal magma chambers (e.g., Larsen et al., 1989; Andreasen et al., 2004). They give no direct insights in to the compositions and origins of the parental and primary magmas. Picritic lavas are not common in the East Greenland plateau basalt succession, but are potential sources for such information. The East Greenland picrite lavas and especially the earliest lavas are, however, often severely affected by burial metamorphism (e.g., Fram and Lesher, 1997; Hansen and Nielsen, 1999). In addition, the picrite lavas contain a spectrum of olivine morphologies, e.g., Nielsen et al. (1981). Although the

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bulk rock compositions of the picrite lavas and dykes would be closer to those of primary, mantle-derived melts, they too may be the result of magma pooling and magma chamber processes.

Melt inclusions in olivine phenocrysts and xenocrysts are a source for information on the compositions of primary magmas (e.g., Gurenko and Chaussidon, 1995; Gurenko et al., 1996; Kamenetsky et al., 1998; Kent et al., 2002; Yaxley et al., 2004; Sobolev et al., 2005). The interpretation of melt inclusion data is, however, often difficult as their compositions vary widely compared to the often well constrained volcanic suites (e.g., Danyushevsky et al., 2004). This reconnaissance study presents analyses and interpretations for melt inclusions from three picrite samples from the East Greenland flood basalt province. The aim is to identify deep and primary, enriched, plume components in the earliest stages of the proto-Iceland plume and to evaluated the potential for a comprehensive study of primary melts in the earliest stages of the proto-Iceland plume from compositions of olivine-hosted melt inclusions.

The data for this study were acquired in the framework of INTAS project 95-953 in 1996-97 and reported in Brooks and Ryabchikov (1998). The present author provided the samples and the background information for the study. Some of the data was presented in Turkov et al. (1998) and Ryabchikov et al. (1998), but only in the form of extended abstracts.

2. The investigated materials

2.1. The Lower Basalts

The up to ca. 1.5 km thick Lower Basalts is a succession of early lavas exposed in the Kangerlussusaq region (e.g. Nielsen et al., 1981; Fram and Lesher, 1997; Hansen and Nielsen, 1999). They are deposited in a continental rift environment and are at their base interbedded with sediments accumulated since early Cretaceous (see, e.g., Nielsen et al., 1981; Larsen et al., 1999; Peate et al., 2003). The Lower Basalts are subdivided into the Vandfaldsdalen Formation and the Mikis Formation (Nielsen et al., 1981) and separated from the overlying regional plateau basalt formations by the Hængefjeldet Formation. The Hængefjeldet Formation is dominated by subaerial and waterlain basaltic tuffs (Nielsen et al., 1981; Peate et al., 2003). The Vandfaldsdalen Formation is a regional succession of lavas deposited in the continental rift system. They are subaerial to the south-west, near the supposed centre of the Kangerlussuaq triple junction and the supposed centre of impact of the proto-Iceland plume under the coast of East Greenland (e.g., Brooks, 1973). They form hyaloclastites and pillow lavas in the deeper, more easterly parts of the rift environment. The overlying, subaerial Mikis Formation appears to form a large, ca. 1 km thick, shield like structure within the rift system (Nielsen et al., 1981).

The picrites of the Lower Basalts are represented by sample GGU 361026 (Table 1) from the lowest 10 m thick picrite flow in the Lower Vandfaldsdalen Formation. The flow is exposed in the eastern wall of Sødalen (Fig. 1; Nielsen et al., 1981; Fram and Lesher, 1997). The investigated sample was collected from a large block on the valley floor. The reason is that the large, broken-up blocks offer much fresher material than can be collected in situ. The picrite sample is massive, dense and contains numeral up to 2 mm large, fresh, olivine phenocrysts and small olivine-clinopyroxene intergrowths in a very fine-grained black matrix composed of clinopyroxene, Fe–Ti oxides, plagioclase and altered olivine and glass. The olivine phenocrysts and the intergrowths are generally fresh and evenly distributed in the flow (see Nielsen et al., 1981 for illustrations and further details). No post-extrusion accumulation of olivine is suggested and the sample is believed to represent the phenocryst-bearing magma.

As other picrite flows from the Lower Basalts, sample GGU 361026 contains three morphologies of olivines: (1) euhedral olivines zoned from 89% to 87% forsterite that appear to be in equilibrium with the bulk composition of the lava (Mg# 0.74; Table 1); (2) embayed and resorbed olivines (up to Fo_{91}) that do not appear to

Table 1
Whole rock compositions

Sample #	361026	404017	40648
Formation	Lower Basalts	Milne land formation	Geikie P. Formation time-equivalent
	Lava	Lava	Dyke
Mg#	0.738	0.744	0.779
SiO_2	45.41	45.72	44.61
TiO_2	1.83	1.33	1.58
Al_2O_3	9.00	8.93	7.07
Fe_2O_3	1.60	1.70	1.89
FeO	9.80	9.95	10.34
MnO	0.19	0.17	0.15
MgO	17.73	18.77	23.80
CaO	8.19	7.10	7.58
Na_2O	1.41	1.21	0.72
K_2O	0.15	0.30	0.24
P_2O_5	0.19	0.16	0.12
Volatiles [a]	2.65	4.34	2.33
Total	98.15	99.68	100.43

XRF analyses by Geological Survey of Denmark and Greenland.
[a] Loss in ignition.